Evaluation of dietary sources of protein on growth performance in pigs

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ABSTRACT: A 6-week trial was conducted to investigate the effects of animal skin protein sources from swine and cattle on growth performance, body condition and blood characteristics in growing pigs. A total of 96 pigs (23.50 ± 0.61 kg) were randomly allotted into four dietary treatment groups as follows: (1) basal diet (BD); (2) basal diet with 1.5% hydrolysed render meal (HRM); (3) basal diet with 1.5% swine skin meal (SSM); (4) basal diet with 1.5% cattle hide meal (CHM). There were six replicate pens per treatment with four pigs per pen. The average daily gain (ADG) was improved in response to SSM treatment compared with other treatments ($P < 0.05$). Pigs fed with HRM, SSM and CHM diets showed increases in average daily feed intake (ADFI) and decreased gain-to-feed (G : F) ratios compared with pigs fed with BD ($P < 0.05$). There were no differences in dry matter (DM), nitrogen (N), and energy (E) digestibility among treatments. The backfat thickness and lean percentage of pigs was unaffected by the treatments. Similarly, there was no difference in blood characteristics among treatments. In conclusion, the supplementation of SSM in growing pig diets improved the growth rate and Feed Intake (FI), but its usage in swine diets is limited by the poor protein quality.

Keywords: animal-derived protein; cattle hide meal; enzyme; swine skin meal; growing pigs

Swine have the ability to obtain nutrients from a wide variety of feedstuffs (Wang et al. 2013). They can consume both plant and animal food sources. In modern feed industry, vegetative feedstuff such as corn and soybean meal represent 80% or more of the total feedstuffs fed to swine (Cromwell 2006; Wang et al. 2011). However, feedstuffs from animal sources have also been used in swine diets (Cho et al. 2010; Cho and Kim 2011; Lei and Kim 2013).

Animal-derived proteins such as meat, bone meal, meat meal, and poultry by-product meal are potentially important protein sources and feed ingredients for swine nutrition because of their amino acid (AA) profiles and crude protein levels (Lee 2001). However, only a small number of reports have evaluated skin-derived proteins in growing pigs. Hydrolysed render meal (HRM) is an unconventional animal-derived protein source for growing pigs which is similar to meat meal. The use of enzymatic digestion as a means of improving the feeding value of by-product feeds has been reported by Woodgate (1994). Further, Lindemann et al. (2000) noted that enzymatic treatment improved the quality of protein. Thus, in our study we developed skin meal directly by enzymatic pre-treatment of raw skin/hide with pepsin. We conducted this trial to evaluate the effects of HRM, swine skin meal (SSM) and cattle skin meal (CHM) on growth performance and blood characteristics in growing pigs.

MATERIAL AND METHODS

The experimental protocol used in this study was approved by the Animal Care and Use Committee of Dankook University.

Preparation of protein sources. The HRM and enzyme-treated skin meal was obtained from the Woosin food company (Pocheon, Gyeonggi, Korea). HRM was produced using a dry processing method at 130 °C and under 500 kpa of steam. Raw swine skin and cattle hide was washed with clean water for 10 min. This washed raw skin was then soaked in 0.5% Na_2S and 0.3 % non-ionic surfactant solution for 18 h. The skin was then removed and washed for 20 min before being soaked in 0.5% Na_2CO_3 for 18 h. Finally, the skin was washed, cut into smaller pieces and pulverised in a mill. The powder was then

Supported by the Research Fund of the Dankook University in 2013.

soaked with 30 volumes of 0.5M acetic acid containing 1% pepsin (1 : 10 000, calculated based on the dry weight of the raw skin) at 4 °C for 48 h. The mixture was centrifuged at 2000 g for 15 min and then the sediment and supernatant were dried separately. The powders were then mixed to obtain the final product.

Experimental design, animals, housing, and diets. A 6-week trial with 96 [(Landrace × Yorkshire) × Duroc] pigs (b.w. = 23.50 ± 0.61 kg) was used to investigate the effect of three sources of protein meal on growth performance, backfat thickness, lean meat percentage and blood profiles. Pigs were assigned to one of four treatment groups in a randomised complete block design according to their sex and b.w. Each treatment group consisted of six replicates with four pigs (two gilts and two barrows) per pen. Dietary treatments were as follows: (1) basal diet (BD); (2) BD with 1.5% hydrolysed render meal (HRM); (3) BD with 1.5% swine skin meal (SSM); (4) BD with 1.5% cattle hide protein meal (CHM). The basal diet used in this experiment was formulated to meet or exceed NRC (1998) recommendations for all nutrients (Table 1). The crude protein, metabolised energy, lysine and methionine levels in the four diets were adjusted to same level. Pigs were housed in a controlled environment with a slatted-floor facility in 24 adjacent pens and were allowed *ad libitum* access to feed and water through a self-feeder and nipple drinker throughout the experimental period.

Sampling and measurements. Individual pig body weights (BW) were measured at the beginning and end (week 6) of the experimental period, and feed consumption was recorded on a pen basis during the experiment to calculate the average daily gain (ADG/F). Chromium oxide was added to the diet as an indigestible marker at 0.20% for seven days prior to faecal collection at the 6th week for calculating apparent total tract digestibility of dry matter (DM), nitrogen (N) and energy (E). Pooled faecal grab samples were collected at random from one gilt and one barrow in each pen. All feed and faecal samples were stored immediately at –20 °C pending analysis. Faecal samples were dried at 70 °C for 72 h and finely ground to pass through a 1-mm screen. The procedures utilised for the determination of the DM, N and gross energy were determined according to the methods established

Table 1. Composition of the experimental diets (as-fed basis)

Ingredients (%)	BD	HRM	SSM	CHM
Corn	56.75	57.68	57.10	56.90
Soybean meal	35.39	32.90	33.50	33.60
HLM	–	1.5	–	–
SSM	–	–	1.5	–
CHM	–	–	–	1.5
Tallow	5.63	5.63	5.63	5.73
Limestone	0.84	0.84	0.84	0.84
Sodium chloride	0.20	0.20	0.20	0.20
TCP	0.70	0.70	0.70	0.70
Lysine	0.14	0.20	0.18	0.18
Ethoxyquin	0.05	0.05	0.05	0.05
Vitamin premix[1]	0.20	0.20	0.20	0.20
Mineral premix[2]	0.10	0.10	0.10	0.10
Calculated composition				
ME (MJ/kg)	14.65	14.65	14.65	14.65
Analysed chemical composition				
CP (%)	19.56	19.76	19.67	19.64
Lysine (%)	1.31	1.32	1.31	1.30
Calcium (%)	0.63	0.65	0.64	0.64
Total phosphorus (%)	0.53	0.55	0.54	0.55

BD = basal diet; HRM = hydrolysed render meal; SSM = swine skin meal; CHM = cattle skin meal

[1]Provided per kg diet: 6500 IU of vitamin A; 950 IU of vitamin D3; 27 IU of vitamin E; 2 mg of vitamin K3; 4 mg of thiamine; 3.6 mg of riboflavin; 1.3 mg of pyridoxine; 23μg of vitamin B12; 26 mg of niacin; 15 mg of Ca-pantothenate; 2 mg of folic acid and 0.03 mg of biotin

[2]Provided per kg diet: 54 mg of Cu; 70 mg of Zn; 50 mg of Mn; 0.5 mg of I; 0.5 mg of Co and 0.25 mg of Se

by the AOAC (2000). Chromium levels were determined via UV absorption spectrophotometry (UV-1201, Shimadzu, Kyoto, Japan) and the apparent total tract digestibility (ATTD) of DM, N and energy were calculated using indirect methods described by Fenton and Fenton (1979). The amino acid composition of soybean meal (SBM), MM, SSM, and CHM was determined using acid hydrolysis with 6N HCl at 110 °C for 24 h using an amino acid analyser (Biochrom 20, Pharmacia Biotech, Cambridge, England) (Table 2). Sulphur-containing amino acids were analysed after cold performic acid oxidation overnight and subsequent hydrolysis. Backfat thickness and lean ratio measurements were performed using a real-time ultrasound instrument (Piglot 105, SFK Technology, Herlev, Denmark) at the beginning and end of this experiment. Blood samples collected from each pig were allowed to clot at room temperature for 1 h and centrifuged at 1500 × g, at 4 °C, for 20 min, and then refrigerated at 20 °C until analysis. Serum constituents including blood urea nitrogen (BUN), creatine and glutamic oxaloacetate transaminase (GOT), glutamic pyruvic transaminase (GPT) were determined by using an automatic biochemistry blood analyser (HITACHI 747, Hitachi, Tokyo, Japan). Average daily feed intake (ADFI) and gain-to-feed ratio (G : F) were also calculated.

Statistical analysis. The data obtained were analysed using the General Linear Models procedure of SAS (SAS 1996) as a randomised complete block design by ANOVA. The pen was considered as the experimental unit. When a significant interaction was observed, the means for each treatment were compared using Duncan's multiple range test (DMRT). Variability in the data is expressed as the standard error and a probability level of $P < 0.05$ was considered to be statistically significant.

RESULTS

The ADG was improved ($P < 0.05$) in response to SSM treatment compared with other treatments. Pigs fed with HRM, SSM and CHM diets exhibited increased ($P < 0.05$) ADFI and decreased ($P < 0.05$) G : F ratios compared with pigs fed with the BD (Table 3). The total tract apparent digestibility of DM, N, and energy was not influenced by the dietary treatments (Table 4). The backfat thickness

Table 2. Amino acid levels in the different protein meals[1]

Amino acids (%)	SBM	HRM	SSM	CHM
		(%)		
Crude protein	48	65	52	48
Essential amino acids				
Arginine	3.11	3.38	3.45	3.00
Histidine	1.08	1.46	1.66	0.98
Isoleucine	1.95	1.31	1.43	1.12
Leucine	3.24	2.99	3.38	2.37
Lysine	2.46	2.01	2.03	1.95
Methionine	0.54	0.58	0.53	0.40
Phenylalanine	2.15	1.83	2.17	1.30
Threonine	1.68	0.98	0.95	1.34
Tryptophan	0.45	–	–	–
Valine	2.16	1.95	2.39	1.45
Non-essential amino acids				
Alanine	1.95	4.47	5.46	3.52
Aspartic acid	5.09	3.46	3.69	3.19
Cysteine	0.63	0.12	0.07	0.17
Glutamic acid	8.22	6.75	7.11	5.20
Glycine	1.89	8.35	10.69	6.73
Proline	2.85	5.82	6.10	4.30
Serine	2.24	1.34	0.90	1.89
Tyrosine	1.67	1.27	1.46	0.81

SBM = soybean meal; HRM = hydrolysed render meal; SSM = swine skin meal; CHM = cattle hide meal

Table 3. Effects of dietary sources of protein on growth performance in pigs

Items	BD	HRM	SSM	CHM	SE[2]
ADG (kg)	0.506[b]	0.494[b]	0.576[a]	0.509[b]	0. 015
ADFI (kg)	1.221[b]	1.429[a]	1.531[a]	1.484[a]	0.047
G : F	0.415[a]	0.345[b]	0.378[b]	0.343[b]	0.010

BD = basal diet; HRM = BD with 1.5% hydrolysed render meal; SSM = BD with 1.5% swine skin meal; CHM = basal diet with 1.5% cattle hide meal; SE = standard error
[a, b]means in the same row with different superscripts differ significantly ($P < 0.05$)

Table 4. Effects of dietary sources of protein on nutrient digestibility in pigs

Item (%)	BD	HRM	SSM	CHM	SE
Dry matter	77.91	78.61	79.12	78.56	0.90
Nitrogen	80.35	81.13	81.64	80.95	0.88
Energy	78.24	77.23	79.06	78.34	1.18

BD = basal diet; HRM = BD with 3% hydrolysed render meal; SSM = BD with 3% swine skin meal; CHM = basal diet with 3% cattle hide meal; SE = standard error

Table 5. Effects of dietary sources of protein on backfat thickness and lean meat percentage in pigs

Items	BD	HRM	SSM	CHM	SE[2]
Week 0					
Backfat thickness (mm)	5.9	6.9	6.9	6.9	0.6
Lean meat percentage (%)	59.9	60.7	60.9	60.5	0.8
Week 6					
Backfat thickness (mm)	9.4	9.8	10.4	9.8	0.4
Lean meat percentage (%)	59.4	59.4	59.3	59.0	0.8

BD = basal diet; HRM = BD with 1.5% hydrolysed render meal; SSM = BD with 1.5% swine skin meal; CHM = basal diet with 1.5% cattle hide meal; SE = standard error

Table 6. Effects of dietary sources of protein on blood profiles in pigs[1]

Items	BD	HRM	SSM	CHM	SE
Week 0					
Creatinine (mg/dl)	0.8	0.8	0.9	0.6	0.1
BUN (mg/dl)	14.4	14.3	15.9	14.5	1.1
GOT (IU/l)	41	41	43	40	4
GPT (IU/l)	31	30	29	29	4
Week 6					
Creatinine (mg/dl)	1.2	1.2	1.0	0.8	0.1
BUN (mg/dl)	13.3	14.3	13.9	13.5	0.8
GOT (IU/l)	53	50	68	66	11
GPT (IU/l)	49	49	47	48	4

BD = basal diet; HRM = BD with 1.5% hydrolysed render meal; SSM = BD with 1.5% swine skin meal; CHM = Basal diet with 1.5% cattle hide meal; SE = standard error; BUN = blood urea nitrogen; GOT = glutamate oxaloacetate transaminase; GPT = glutamate pyruvate transaminase

and lean meat percentage was unaffected by dietary treatments (Table 5). No differences were observed in blood concentrations of creatinine and BUN. The activities of serum GOT and GPT did not differ among the different dietary treatment groups (Table 6).

DISCUSSION

According to the report of Grant and Jackson (1976), collagen constitutes over 70% of the dry weight of skin, tendon and cartilage. Meat and bone meal may

contain 21–61% bone, and bone protein has 83% collagen (Evans and Leibholz 1979); thus, 50–65% of the total protein in meat and bone meal could be collagen. This is similar to the composition of meat meal protein. Meat and bone meal is widely used in animal feed and has been well investigated (Franco and Swanson 1996; Traylor et al.2005). In our experiment, HRM, SSM and CHM were used to replace the soybean meal at a level of 1.5%, and we observed that HRM did not influence the growth rate of growing pigs. Meanwhile, pigs fed with SSM diet exhibited the best growth rate but also displayed the highest FI and poorest G : F ratio. Pigs fed with the soybean meal diet had a similar growth rate but a lower FI and the best G : F ratio. Early research in pigs indicated that growth performance decreased with increasing levels of meat and bone meal in diets (Peo and Hudman 1962; Evans and Leibholz 1979). We hypothesised that skin-derived protein limits the growth of pigs at the level of 1.5%. Animal by-products contain low levels of tryptophan and the amino acids in these animal-derived proteins were found to be imbalanced (Cromwell et al. 1991). This may be one of the factors which influence the nutritional quality of skin-derived protein. Interestingly, Kennedy et al. (1974) also reported that pigs fed a soybean meal diet had better growth performance, higher organic and dry matter digestibility, and nitrogen retention than those fed with meat and bone meal diets. In our trial, the growth rate of pigs in response to SSM treatment was found to be higher than other treatments especially in the CHM which was treated in the same way as the SSM. Thus, we hypothesised that SSM mirrors swine body protein with respect to the AA component. In the present study, the apparent total tract nutrient digestibility of DM, N, and E was unaffected by the dietary treatments. Thus, the sharply increased FI in response to SSM treatment may be responsible for the high growth rate in the SSM treatment group. We analysed the amino acid profile for HRM, SSM and CHM groups and found that proline, arginine, glumatic acid, and leucine content in SSM were higher than in HRM and CHM. Recent studies suggest that proline may play a role in regulating the mammalian target of rapamycin (mTOR) signalling pathway (van Meijl et al. 2010), which integrates signals from nutrients (glucose and AA), cellular energy status, growth factors, and various stress factors that affect cell growth and function (Liao et al. 2008; Li et al. 2009). Proline acts in concert with arginine, glutamine, and leucine (activators of mTOR and regulators of polyamine production) to enhance protein synthesis in cells and tissues (e.g. the small intestine and skeletal muscle) (Wu et al. 2010).

In the pork industry, lean meat proportion is an important carcass quality index (Hulsegge et al. 2000). Backfat thickness measured by ultrasonic techniques represents one of the methods for predicting the lean meat proportion of live pigs (Alliston et al. 1982; Turlington 1990; Gresham et al. 1992). There are many factors shown to be related with backfat thickness and lean meat proportion, including genotype, diet, sex and temperature (MacGrath et al. 1968; McPhee and Daniels 1991; Dunshea et al. 2002). However, similar studies in pigs fed with animal-derived protein showed varying effects on backfat thickness. Seerley (1991) reported that pigs fed with meat and bone meal exhibited an increase in average backfat and a decrease in loin muscle area compared to those fed with SBM. However, Traylor et al. (2005) reported that the dietary meat and bone meal did not affect backfat thickness. This last study is consistent with our results, where backfat thickness and lean meat proportion were unaffected by the different dietary treatments. In this trial the levels of supplements in the HRM, SSM, and CHM groups were at identical levels. Further studies should be conducted to evaluate the effect of dietary constituents on growth and carcass quality.

It is well accepted that BUN can be inversely related to the efficiency of nitrogen (Eggum 1970; Orok and Bowland 1975; Bassily et al. 1982; Coma et al. 1995), and its reduction is generally associated with an increase in the efficacy of nitrogen and lean gain (Berschauer et al. 1983; Whang and Easter 2000). Various studies have suggested that BUN is directly related to protein intake and protein quality (Lewis and Speer 1973; Robles-Cabrera and Speer 1983). Awosanya et al. (2000) also reported that blood protein and creatinine levels were dependent on the quality of dietary protein. In the current study, BUN and creatinine levels were not influenced among the dietary treatments. However, BUN levels in the SSM treatment group were lower in the 6^{th} week than at the commencement of this experiment (13.9 versus 15.9 mg/dl). This partly explains the high growth rate in SSM-treated animals. In mammals, GOT is an enzyme which is widely distributed in many tissues and organs, especially in the liver (Zimmerman et al. 1968). Elevated GOT activity usually indicates liver or muscle damage, but no particular significance is associated with low GOT activity (Meyer and Harvey 1998). Glutamate pyruvate transaminase (GPT) is not a liver-specific

enzyme (Kramer and Hoffman 1997) and its activity in plasma is influenced by age and muscle activity (Weigert et al. 1980). GOT and GPT activities were not influenced by the dietary treatments reflecting the fact that the health condition of the pigs was normal and underlining that the dietary treatments did not affect animal health status.

In conclusion, the results of the current study indicate that dietary supplementation of HRM, SSM and CHM leads to increased ADFI and decreased gain-to-feed ratios compared with pigs fed with BD. Further, the supplementation of SSM to growing pig diets improved growth rate and feed intake.

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Received: 2014–03–15
Accepted after corrections: 2014–06–29

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